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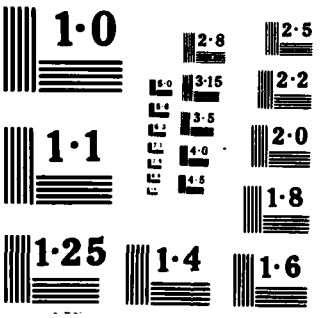
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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD ADVISORY REPORT No.218

Technical Evaluation Report on the Electromagnetic Wave Propagation Panel Symposium on Propagation Effects on Military Systems in the High Latitude Region

NORTH ATLANTIC TREATY ORGANIZATION

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.218

TECHNICAL EVALUATION REPORT

on the

ELECTROMAGNETIC WAVE PROPAGATION PANEL SYMPOSIUM

on

PROPGATION EFFECTS ON MILITARY SYSTEMS

IN THE HIGH LATITUDE REGION

by

R.D.Hunsucker
Geophysical Institute
University of Alaska
Fairbanks, Alaska, USA

This Advisory Report was produced at the request of the
Electromagnetic Wave Propagation Panel of AGARD.

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The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

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- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
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TECHNICAL EVALUATION REPORT

Professor Robert D. Hunsucker, Ph.D.
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99775-0800
USA

Introduction

The 36th Symposium of the AGARD Electromagnetic Wave Propagation Panel (EPP) was held at the University of Alaska in Fairbanks, 3-7 June, 1985, with the title "Propagation effects on military systems in the high latitude region". The chairman of the EPP, Dr. J. H. Blythe was assisted by the Technical Program Committee (Chairman, Dr. H. Soicher), the AGARD panel Executive, Lt. Col. T. B. Russell and the Host Nation coordinator, Professor R. D. Hunsucker in facilitating a stimulating symposium which had both technical breadth and depth. Some 70 scientists, engineers and administrators representing eleven NATO countries and Australia presented 43 papers, took three technical tours, participated in a 1 1/2 hour roundtable discussion and in many informal technical discussions. (See Appendix A for a listing of the specific papers presented and Appendix B for a list of symposium participants.

Theme

The following theme of the symposium taken from the meeting announcement explains cogently how and why the Symposium topic was selected.

"With the advent of new systems operating at high latitudes in the field of detection, navigation and communications and with the new experiments at high latitudes ranging from incoherent scatter studies to satellites for studying high latitude irregularity structure, it is of considerable importance to relate the advances in high latitude studies to military systems. The concept of this proposal for a meeting on propagation effects on military systems in the high latitude region is to bring together these two areas.

The behavior of the propagation environment at high latitudes differs from that at lower latitudes, affecting radiowave propagation across the RF spectrum. The differences are ascribed to rugged terrain, severe climatic conditions, and influences of the interplanetary and magnetospheric geophysical events which are guided earthward by the geomagnetic field.

The high-latitude ground region is characterized by a rugged terrain and a tremendous variation in ground electrical characteristics.

The severe climatic conditions include a large daily and seasonal temperature variation, extremes of temperatures, high winds, ice accumulation, precipitation (rain, snow, ice crystals, sleet, hail), surface and elevated temperature inversions which produce large refractive gradients and ducts.

The high latitude ionosphere is affected by two major phenomena: energetic particles from the sun and from the outer magnetosphere penetrate the atmosphere and create ionization at various altitudes; and the solar wind induces an electric field perpendicular to the magnetic field which causes ionization drifts and thus contributes to the formation of ionization irregularities. Some of the ionospheric propagation anomalies created include: auroral oval absorption and polar cap absorption; sporadic E, small scale irregularities (spread F) giving rise to scattering and fading phenomena and causing trans-ionospheric amplitude and phase scintillations; effects of magnetic substorm activity, density troughs, and large sheets of field-aligned ionization.

The symposium will direct its efforts towards propagation problems and solutions for many systems. These topics include satellite communication over polar and auroral latitudes, over-the-horizon radar, low frequency propagation under high latitude conditions, remote sensing of high latitude regions by active and passive EM systems, and HF communications at auroral and polar latitudes. Unique lower atmospheric effects and multipath problems of importance at high latitudes will also be discussed.

With the NATO northern flank nations (in both the European and North-American sectors) situated in the high-latitude region, with NATO air routes across the Atlantic traversing that region, and with surveillance and early-warning systems looking in the direction of the region, the propagation characteristic of the high-latitude region are of critical importance to the mission of the alliance in the areas of communications, navigation and surveillance."

Purpose and Scope

The purpose of this meeting was to bring together ionospheric physicists, communications and systems engineers, plus managers and users of communications and surveillance systems from the NATO countries to exchange information on the subject of the symposium. Included in the scope of the meeting were: (1) detailed experimental studies of ionospheric irregularities and regular structure, (2) results of ionospheric modification (HF heating) experiments, (3) theoretical studies of ionospheric irregularity formation, (4) a global survey of ground conductivities, (5) results of disturbance modeling studies, and (6) high latitude effects on the following systems: a) HF radio communication, b) Trans-ionospheric communications, c) Satellite synthetic aperture radar (SAR), d) MF radio broadcasting, e) Spatially adative propagation, f) HF digital, g) Skywave HF sea-state radar and h) meteor burst communication.

The actual titles of the symposium sessions were:

I. Overview (2 papers)
II. Transionospheric Propagation and Considerations (9 papers)
III. Propagation Aspects of HF Communications (6 papers)
IV. High Latitude HF Probing (7 papers)
V. Ionospheric Modification (2 papers)
VI. Incoherent/Coherent Scatter (4 papers)
VII. Measurement Techniques/Models/Morphology and Physics (5 papers)
VIII. Low-Frequency Propagation (3 papers)
IX. Meteor Burst/Scatter (2 papers)

Evaluation

This section is an attempt to distil the essence of the following items:

A) The Session chairmen's summaries
B) The TER author's evaluation of salient papers
C) The Round Table discussion
D) The TER author's assessment of the overall technical-scientific situation viz á viz AGARD/NATO

The TER author is responsible for the selection, paraphrasing and editing of information from items A and C and bears sole responsibility for opinions expressed in items B and D.

A. Session Summaries

Session I There were two invited review papers; "Solar-terrestrial relationships in the high latitude region" (#1.1), by Professor S.-I. Akasofu of the University of Alaska, and "Media effects on systems in the high latitude region" (#1.2), by Dr. E. Thrane of NDRE-Kjeller, Norway. Paper 1.1. discussed how the magnetosphere responds to the interplanetary magnetic field (IMF) and to the characteristics of the solar wind. This analysis technique makes it possible to predict the geometry of the auroral oval and the intensity of a geomagnetic storm as a function of time if the IMF and solar wind parameters are known. Thrane reviewed the transmission media effects across the radio spectrum at high latitudes, including high latitude propagation effects on the important signal parameters. He concludes that modern technology makes it possible that communications and sensing systems can adapt to the high latitude propagation conditions, but that accurate modeling of this medium is necessary.

Session II Over the last 20 years, the morphology of high latitude irregularities at high latitudes has been explored. These irregularities can be divided into 1. - polar cap, 2. - auroral, 3. - trough and 4. - plasmapause regions. The scintillation studies have clearly shown that auroral irregularities are a function of geomagnetic index, time of day and solar flux. Polar irregularities morphology is also generally understood. The first measurements of total electron content were reported at this conference, giving more information on the extent of polar irregularities including their form and velocity. More importantly there were attempts to link the irregularity studies to large-scale probing of the ionosphere-magnetosphere interaction. The future holds the possibility of understanding the processes that link the high-latitude ionosphere to the magnetosphere and eventually to the sun. The interaction of these physical studies with propagation measurements will lead to means of forecasting and predicting fading of transionospheric signals and to methods for reducing the effects of F-layer irregularities on transionospheric satellite propagation.

Session III The papers by Darnell, Goutelard and Caratori concerned how improved equipment and system design could overcome the problems associated with high latitude propagation. The papers by Quegan, Milsom and Herring and by Damboldt addressed ionospheric modeling at high latitudes, and at mid-latitudes during disturbed periods. The paper by Cormier, et al., described a new experiment between Thule and Goose Bay to measure azimuth and elevation arrival angles of HF skywave signals and illustrated the variability of the auroral ionosphere.

Hunsucker, et al., compared theoretical predictions with experimental results for medium frequency (MF) skywave signals received at Fairbanks, Alaska, and concluded that these signals were dominated by D-region absorption and that the FCC standard curves should include some variability for auroral latitudes.

Session IV This session was devoted to measurements at high latitudes, five of the papers dealt with oblique backscatter and two described zenithal sounders. The reports presented show that the measurements taken in high latitudinal regions are particularly difficult, notably because of the complexity of the phenomena which develop there. They imply the implementation of complex systems, and the results show the necessity of following up these studies in the years to come.

Session V Intentional modication (or heating) of the ionosphere by high-powered radio waves continues to be a subject involving much experimental and theoretical interest. Ionospheric changes that result from such heating are on a wide range of spatial and temporal scales. Such changes permit detailed investigation of the physical processes occurring through observations of the amplitude, phase and spectral content of radio waves that traverse the heated volume.

Session VI Bauer reviewed recent scientific work using EISCAT. Results of large, medium and small scale studies were discussed, and comparisons between EISCAT and the STARE radar measurements were communicated.

In order to investigate small structures in the high latitude F-region, Hargreaves et al., have used beam scanning of EISCAT. The magnitudes of irregularities observed in four runs between 1982 and 1984 are analyzed with periods shorter than 2 minutes. Field aligned irregularities of scales of more than a few kms can be traced by the EISCAT UHF radar up to heights of about 700 km.

Kofman and Lathuillere used EISCAT to investigate the response of the ionospheric plasma to the energy deposition of particle precipitation during disturbed conditions as compared to undisturbed situations. They obtained results on the change of ion composition in response to electron precipitation and Joule heating, and on the variation of neutral density and temperature depending on the energy input.

Jones et al., presented results obtained from experiments with the SABRE radar. The strongest backscatter between 13-19 UT and 23-03 UT was found associated with the main electrojets, and only weak backscatter occurred around the convection reversals. The aspect angle attentuation can take any value between 0 and 10 dB per degree depending on the absolute intensity measured. The characteristics of the backscatter irregularities are important to estimate the qualty of communications and surveillance systems operating in either HF or VHF frequency bands at these latitudes.

Session VII As suggested by the session title, a variety of subjects were discussed. The first paper by Taagholt gave an overview of geophysical measurements in the Greenland area, emphasizing the importance of this area for Arctic radio propagation and giving examples of the very considerable activity initated by Danish and US agencies.

Modelling of the Arctic propagation medium was addressed in two papers by Watkins and Hargreaves. The two authors had very different approaches: Watkins described a three dimensional ionospheric model based on physical processes governing solar-terrestrial interactions, whereas Hargreaves presented a statistical model for ionospheric absorption based on riometer measurements at arctic stations.

Lee described an interesting study of the physical mechanisms responsible for the generation of high latitude ionospheric irregularities. Progress is being made in this field, which is of great importance for radio systems in high latitudes.

The final paper in the session dealt with phenomena in the mesosphere. Dr. Widdel presented new results from tracking of chaff clouds. These measurements provide new insight into the dynamical processes in the non-ionized air in the lower ionosphere. These processes are of importance for the understanding of the coupling between the ionized and neutral species.

Session VIII Field presented lower ionosphere conductivity profiles which were derived from oblique VHF soundings in North Greenland during a large solar proton event. The results were compared with conductivity data derived from satellite measurements of the proton flux, at various energies. Although the results obtained from the two data sources differ, both methods show a conductivity during a solar proton event, which exceeds the conductivity during undisturbed conditions, by two or more orders of magnitude.

Prolss presented a study which comprises theoretical calculations and measurements of lightning discharges. The maximum spectral energy of the pulses are typically in the 5-9 KHz frequency range. The lightning discharges seem to be the predominant natural source of electromagnetic energy in this frequency range, and the analysis has shown, that it is possible to determine the propagation characteristics of the Earth - Ionosphere waveguide at VLF frequencies, by receiving the signals from this source at a distant location. In addition, it is possible to determine the location of thunderstorm areas.

In a second paper, Field presented a study which concerned unexpected attenuation of ELF signals in the Gulf of Alaska during PCA events. Calculations show that the attenuation might be caused by refraction of the ELF field into the Polar Cap during PCA events.

Stokke discussed ground conductivities with particular emphasis on the high latitude region. The earth's conductivity is a determining factor for low frequency propagation. Typical values of arctic ground conductivity, which can vary by six orders of magnitude for different types of terrain was presented. The importance of including information on the seasonal variation of the earth conductivity in the Arctic areas in the first edition of the CCIR conductivity atlas was discussed. An atlas is planned for publication during the fall 1985.

Session IX This session comprised just two papers. However, in combination they give a rather complete account of the current state of the art. Meteor Burst Communication (MBC) systems were actively studied in the 50's and have been under review ever since, but have never been used significantly in military systems. Recent advances in receiver systems and integrated circuit technology have led to renewed interest, reflected in the two papers, which concentrate on aspects relevant to high latitudes.

The two papers form a valuable complementary pair, showing that data is being gained which would enable system design to be undertaken with confidence in the event of a decision to deploy. This data covers many new aspects which were not addressed in earlier studies, such as the integrity of security in various propagation events, the effect of polarization rotation, and the overall influence of frequency.

B. Comments on Some Salient Papers

The following discussion contains summaries by the TER author of papers in the order they were presented at the symposium which he considered to be of the most importance to the mission of NATO as defined by AGARD.

Welcoming address by Professor Juan Roederer.

Professor Roederer, Vice Chairman of the U.S. Arctic Research Commission and Director of the Geophysical Institute of the University of Alaska, described the developments leading to signing

into U.S. law the formation of the Arctic Research and Policy Act of 1984 which establishes an Arctic Research Commission and an Interagency Arctic Research Policy Committee. It designates the National Science Foundation as the lead agency responsible for implementing arctic research policy. It mandates the formulation of a comprehensive five-year Arctic Research Plan and it requires the preparation of a single, integrated multiagency budget request for arctic research.

In the fields of research of NATO/AGARD interest, some important recommendations and related priorities are being considered.

Concerning defense-related issues, the following research areas are being identified as needing special emphasis:

1. To improve the reliability of prediction of auroral, ionospheric and magnetic disturbances in the Arctic regions.

2. To study the mechanisms responsible for the formation of ionospheric inhomogeneities and their effects on electromagnetic wave propagation.

3. To obtain a long-term data base and to maintain a real-time information flow on the natural electromagnetic and particle radiation background using ground-based, rocket and satellite techniques.

The present AGARD Symposium dealt with a research subject that will be given high priority by the Arctic Research Commission, and which in its applied aspects, is already receiving high priority in the framework of the general Arctic Policy that is being forged by the President.

The new U.S. Arctic Policy decisions should be welcomed not only by the United States scientific community with interests in the Arctic, but also by the residents of the Arctic, by the private sector operating in the Arctic, and by our NATO partners.

Session I - Paper 1.1. Professor S.-I. Akasofu, "Solar-terrestrial relationships in the high latitude Region". Akasofu presented a prediction scheme which has as inputs the solar wind parameters and the vector description of the interplanetary magnetic field, then uses a very sophisticated computer modeling scheme to obtain the geometry of the auroral oval and the intensity of the geomagnetic storm - which are the main parameters of use to model the disturbed high-latitude ionosphere. The paper by Watkins, et al., in Session VIII extends these results to the polar ionosphere.

Session I - Paper 1.2. Dr. Eivand Thrane, "Media effects on systems in the high latitude region", Thrane - gives a good review of the salient media effects.

Session II - Paper 2.2. Dr. J. A. Klobuchar, et al., "Total electron content and L-band amplitude and phase scintillation measurements in the polar cap ionosphere", presented the first measurements of absolute total electron content (TEC) and L-band amplitude and phase scintillations from a polar cap station. The observations showed a 100% increase in TEC above background levels, sometimes lasting for over two hours. Phase scintillations were highest during some of the enhanced TEC periods. These results should be applicable to the design and operation of L-band satellite systems operating in the polar cap.

Paper 2.4. - Dr. Jules Aarons, "F layer irregularities at plasmapause and auroral latitudes" - summarized the morphology of F-layer irregularities in two latitude regions of considerable importance to radio propagation - the plasmapause and auroral latitudes.

Paper 2.8. - Dr. S. Talbot, et al., "EHF/SHF ray bending", showed that ray bending was about 0.1° for 10° elevation angles to about 0.75° for 0° elevation angle under standard atmospheric conditions. This bending was nearly independent of frequency in the SHF/EHF range. These results have implication on tracking and spatial acquisition for satellites at high latitudes.

Session III - Paper 3.2. Dr. S. Quegan, et al., "Ionospheric modelling and HF radio systems at high latitudes" - describes a physically-based numerical model of high latitude ionospheric structure which is at a fairly advanced state of development. When completed, it should provide better HF system performance.

Paper 3.3. - Dr. M. Darnell, "Techniques for improving the reliability of mobile HF communications over high-absorption paths", presented description of a system which uses various forms of diversity processing, relaying, meteor burst and ionospheric scatter modes and modulation and coding schemes to increase the reliability of high latitude HF mobile communication.

Session IV - Paper 4.5 - Dr. R. A. Greenwald, et al., "Observations of very high latitude ionospheric irregularities with the Goose Bay HF radar", provided information on the morphology of F-region irregularities in the latitude range of importance to some OTH radar systems.

Papers 4.6 and 4.7. - Dr. Berkey, et al., and Mr. Rodger, et al., respectively, "Observations of the main ionospheric trough from Antarctica", these papers, taken together describe the variability of the trough, which is a governing factor for HF propagation between midlatitudes and higher latitudes.

Session V - Paper 5.1. - Dr. T. B. Jones, et al., "The influence of ionospheric heating on the propagation of HF waves", an excellent review of how ionospheric modification can markedly affect HF propagation.

Session VI - Paper 6.1. - Dr. P. Bauer, "EISCAT: A review of recent scientific works", results obtained using the EISCAT system in northern Scandinavia, such as - plasma convection and heating in the auroral oval, particle precipitation, etc., are described. The EISCAT radar provides

excellent data describing the ionospheric conditions for NATO northern area HF communications.

Paper 6.4 - Dr. T. B. Jones, et al., "SABRE radar observations in the auroral ionosphere". This VHF radar system provides a comprehensive picture of E-region structure and dynamics in the ionospheric region off the central west coast of Norway.

Session VII. - Paper 7.1 - Dr. Jorgen Taagholt, "Danish and U.S. geophysical measurements in Greenland and surrounding areas related to arctic radio propagation", describes the large array of geophysical instrumentation in and near Greenland which can quite comprehensively describe the ionosphere from 60° to 80° geographic latitute in an area of considerable strategic importance for north Atlantic radio communication.

Paper 7.2. - Dr. B. J. Watkins, "Progress in modelling the polar ionosphere from solar and magnetosphere parameters", as mentioned in the Section I Summary, this paper is complementary to Dr. Akasofu's paper and extends the prediction and modelling scheme to include the polar ionosphere.

Session VIII - Paper 8.1 - Dr. E. C. Field, et al., "Effects of the ionosphere on ELF signals during polar cap absorption events: Comparison of theory and experiments" - gives a 2D computer ray-tracing analysis of conditions in the polar D-region which may have influenced a severe ELF signal loss at a submarine in the Gulf of Alaska. Could be of use in similar communication scenarios.

Paper 8.4. - Dr. K. N. Stokke, "World atlas of ground conductivities with particular emphasis on the high latitude region", described methodology and contents of a forthcoming CCIR Atlas on ground conductivities which should be of help in designing systems and communication links at high latitudes.

Session IV - Papers 9.1 and 9.2 - Dr. P. S. Cannon, et al., and by Dr. J. Ostergard et al., - these complementary papers review meteor burst communication (MBC) and describe some recent results pertaining to design and implementation of the MBC mode, which has considerable utility for some NATO communications requirements.

C. Summary of Round Table Discussion

A lengthier description of the Round Table Discussion held during the last session of this symposium by Professor Hunsucker is included in AGARD-CP-382, so only the highlights will be included in the TER.

Four questions were posed to Symposium participants the day before the Panel Discussion.

1. In the context of the subject of this symposium (Propagation effects on Military Systems in the High Latitude Region), what is the state of our understanding at this time?

2. What answers has this symposium provided?

3. What directions for future research?

4. What operational needs require this understanding?

The four Round Table Discussion panel members' statements are herewith summarized.

Dr. R. A. Greenwald (U.S.) - Discussed the differing points of view of the ionospheric physicists (researchers) and the communications and radar system operators and designers ("users") and concluded that people who are users should give a bit more attention to what is going on in the research community and see how the results and equipment used by researchers might be supported and might lead to improved understanding of their problem.

Dr. Piere Bauer (France) - emphasized the need for good physical characterizations of specific communication channels and pointed out the importance of using incoherent scatter radars and other radio techniques together to help solve the ionospheric research problems. He also stressed the importance of constructing complete, accessible uniformly formatted data bases.

Dr. G. Rose (W. Germany) - reviewed the capabilities of ionospheric modification (heating) techniques to learn the physics of the ionosphere, and indicated some practical communication applications.

Dr. E. Thrane (Norway) - described his experience with present versions of ionospheric propagation prediction schemes and made a plea for improving these prediction programs by utilizing presently existing ionospheric data bases.

Mr. Alan Rodger (U.K.) - stressed the importance of utilizing simple ionosonde data to supplement incoherent scatter data on the ionosphere. He also mentioned the use of coherent backscatter systems added to the other systems to obtain a data base to include ionospheric models. In closing, he stressed the importance of validating northern hemisphere ionospheric models in the Antarctic because the solar and geophysical coordinate system down there is fundamentally different - also he stressed the importance of the midlatitude trough physics for radio propagation studies.

After the panel members presentations, a rather lively audience participation ensued. The gist of most discussions concerned the needs of the users - the common perception being that they are quite often unmet in ionospheric research - and the concerns of the physicists that they needed adequate support and time to produce physically correct models.

The following closing comments were made by the Chairman of the Round Table Discussion.

In addition to the foregoing discussion, some conference participants submitted written responses to the four questions posed at the start. The following points were salient in the written responses.

1. The EPP should continue to study the arctic ionospheric effects on radio systems.
2. The arctic regions have a very strong strategic position in the NATO radio communication system.
3. HF modes may be one of the last means of communication in a conflict.
4. Future meetings should contain at least one classified session to ensure that specific needs are being met.

Conclusions

This 36th Symposium of the AGARD Electromagnetic Wave Propagation Panel (EPP) has reinforced the conviction that the high latitude environment has profound effects upon specific military systems such as OTH radar, HF "analog" and digital communication systems, and EHF/SHF satellite navigational systems. Furthermore, there seems to be a very favorable juxtaposition of advances in ionospheric modeling, radio research techniques, and to a lesser extent, theoretical studies in the mid 1980's which can ameliorate these high latitude effects. To give two examples, recent advances in integrated circuit and receiver technology suggest that Meteor Burst Communication (MBC) systems offer a viable method of achieving secure medium-range point-to-point comunication; while advances in equipment and system design now make operational HF Mobile adaptive networking systems possible.

The table below is an effort to summarize the status of development of elements of the research Triad of "Theory-Experimental Results - Modeling" as a function of some specific military systems. The letters G = Good, F = Fair, and P = Poor express the TER author's opinion.

In the High Latitude Region
Adequacy of:

Specific Radio System	Theory	Experimental Results or Data Base	Model (Simulation)	Comments
HF Digital Comm., HF voice point-to-point HF Mobile	G	G	F	In the next 5 years quite good models should be available
OTH Radar	F	F - G	F	Data available from new techniques is now becoming available
Meteor Burst Comm. (MBC)	G	P - F	?	Holds considerable promise in near future
Satellite Navigation Satellite Surveillance (SAR) Satellite Comm.	F - G	F - G	F	New data are becoming available
MF Broadcasting	G	P	P	New data are becoming available
ELF Comm.	F - G	F	F - G	Improved models are becoming available
Ionospheric Modification	F - G	F - G	F	Considerable information is now available

The need for "interpreters" to communicate the results of theory, experiment and modeling to the "user community" became apparent during this symposium. "Users" need to be cognizant of recent research findings in order to ask the correct questions, and researchers need to be aware of specific user needs in order to "fine tune" some of their research efforts. Vehicles such as the AGARD/EPP Symposia are necessary, but not sufficient in themselves. Individuals must also take positive steps to improve communication between these groups.

Recommendations

1. Continue the AGARD/EPP Symposia and Lecture series.
2. Attempt to identify good "interpreters" between the communities.
3. Increase the awareness of the radio research community of the AGARD/EPP meetings and encourage more scientists to participate.
4. NATO/AGARD should further encourage visits and exchanges between radio researchers and users - even possibly visits to selected communication facilities.
5. Perhaps there should be wider dissemination of AGARD Conference Proceedings and other reports.

APPENDIX A

PROPAGATION EFFECTS ON MILITARY SYSTEMS IN THE HIGH LATITUDE REGION

PROGRAMME

Monday, 3 June 1985

Session I - Overview

Chairman: Dr. H. Soicher (US)

0930 1.1. Solar Terrestrial Relationships in the High Latitude Region (Invited Review)
S.-I. Akasofu, University of Alaska, Fairbanks, Alaska, US

1015 1.2. Media Effects on Systems in the High Latitude Region (Invited Review)
E. Thrane, NDRE, Kjeller, NO

1025 Break

Session II - Transionospheric Propagation and Considerations

Chairman: Dr. J. Aarons (US)

1100 2.1. Recent Hilat Results (Invited Review)
E. Fremouw, Physical Dynamics, Inc., Bellevue, WA, US

1130 2.2. Total Electron Content and L-Band Amplitude and Phase Scintillation Measurements of the Polar Cap Ionosphere
J. A. Klobuchar, G. J. Bishop, AFGL Hanscom AFB, MA and D. H. Doherty, Emmanuel College, Boston, MA, US

1200 2.3. Variability of Transionospheric Signal Time Delay at High Latitudes Near Solar Minimum
H. Soicher, U. S. Army CECOM, Fort Monmouth, NJ, US

1230 Lunch

1400 2.4. F-Layer Irregularities at Plasmapause and Auroral Latitudes
J. Aarons, Boston University, Boston, MA, US

1430 2.5. Influence of Polar Irregularity Shape and Velocity on the Design of Airborne Satellite Communications Systems
A. L. Johnson, USAF Avionics Lab, Wright Patterson AFB, OH, US

1500 2.6. Propagation Effects on Satellite-Borne Synthetic Aperture Radars
C. L. Rino and J. Owen, SRI International, Menlo Park, CA, US

1530 Break

1600 2.7. High-Latitude Scintillations using NNSS Satellites
L. Kersley, University College of Wales, Aberystwyth, UK

1630 2.8. EHF/SHF Ray Bending
S. Talbot, RADC Griffiss AFB, New York, D. Providakes, D. Zimmerman and D. Post, MITRE Corporation, Bedford, MA, US

1700 2.9. E.H.F. Propagation Measurements along Satellite-Earth Paths in the Canadian High Arctic
I. Lam and J. I. Strickland, CRC, Ottawa, CA

Tuesday, 4 June 1985

Session III - Propagation Aspects of HF Communications

Chairman: Dr. P. Cannon (UK)

0930 3.2. Ionospheric Modelling and HF Radio Systems at High Latitudes
S. Quegan, J. D. Milsom, and R. N. Herring, GEC Research Labs, Marconi Research Centre, Chelmsford, UK

1000 Break

1030 3.3. High Latitudes Spatially Adaptive Propagation Experiment
R. J. Cormier, E. Tichovolsky, RADC, Hanscom AFB, MA and R. Greenwald, Johns Hopkins University, Laurel, MA, US

1100 3.5. Techniques for Improving the Reliability of Mobile HF
M. Darnell, University of York, UK

1200 Lunch

1330 3.6. Propagation Characteristics of Medium Frequency Skywave Signals from the Continental US and Canada Received at Fairbanks, Alaska
R. D. Hunsucker, B. S. Delana, University of Alaska, Fairbanks, AK and J. C. H. Wang, FCC, Washington, D.C. US

1400 3.7. Optimization of HF Digital Radio Systems at High Latitudes
C. Goutelard and J. Caratori, University of Paris-Sud, FR

1430 3.8. Observations with an Ionosonde in Northern Germany near the Mid-Latitude Trough
T. Damboldt, Forschunginsstitut der DBP, Darmstadt, FRG

1500 Break

Session IV - High Latitude HF Probing

Chairman: Prof. C. Goutelard (FR)

1530 4.1. Ionospheric Factors Affecting the Performance of HF Sky-Wave Sea-State-Radars at High Latitudes (Invited Review)
P. A. Bradley and A. J. Gibson, Rutherford Appleton Lab, Chilton, UK

1600 4.2. Spectral Characteristics of High Frequency Waves Backscattered by Small Scale F region Irregularities: Evidence of Strong Sub-Auroral Ion Flow
A. Bourdillon, Laboratoire Exosphere, Paris, FR

1630 4.3. Small-Scale Irregularities in the High-Latitude F-Region
C. Hanuise, J. P. Villain, LSEET/CNRS, Toulon, C. Beghin, LPCE/CNRS, Orleans, and G. Caudal, CNET-CRPE, St. Maur les Fosses, FR

1700 4.4. On the Relationship of F Region Structure in the Dayside Auroral Oval to HF Backscatter Signatures Attributed to the Polar Cusp
J. D. Kelly, R. T. Tsunoda, SRI International, Menlo Park, CA, US, J. K. Oleson and P. Stauning, Danish Meteorological Institute, Copenhagen, DE

Wednesday, 5 June 1985

Session IV - Continued

0830 4.5. Observations of Very High Latitude Ionospheric Irregularities with the Goose Bay HF radar
R. A. Greenwald and K. B. Baker, APL/Johns Hopkins University, Laurel, MD, US

0900 4.6. Observations of the Mid-Latitude Ionospheric Trough from Antarctica
F. T. Berkey, Utah State University, Logan, UT, US and M. Jarvis, British Antarctic Survey, Cambridge, UK

0930 4.7. The Variability and Predictability of the Main F-Region Trough Determined Using Digital Ionospheric Sounder Data
A. S. Rodger, J. R. Dudeney, British Arctic Survey, Cambridge, UK

1000 Break

Session V - Ionospheric Modification

Chairman: Dr. G. Rose (FRG)

1400 5.1. EISCAT: A Review of Recent Scientific Works (Invited Review)
P. Bauer, CNET-RPE, Issy-les-Moulineaux, FR

1445 5.2. Irregular Structures in the High Latitude F-Region Observed Using EISCAT Incoherent Scatter Radar
J. K. Hargreaves, C. J. Burns and S. C. Kirkwood, University of Lancaster, Lancaster, UK

1515 Break

1545 6.3. Observations of the Auroral Ionosphere Using EISCAT
W. Kofman and C. Lathuillere, CEPHAG, Domaine Universitaire, Grenoble, FR

1630 6.4. Sabre Radar Observations in the Auroral Ionosphere
T. B. Jones, J. A. Waldock, E. C. Thomas, C. P. Stewart and T. R. Robinson, University of Leicester, UK

Thursday, 6 June 1985

Session VII - Measurement Techniques/Models/Morphology and Physics

Chairman: Prof. E. THRANE (NO)

0830 7.1. Danish and US Geophysical Measurements in Greenland and Surrounding Areas Related to Arctic Radio Propagation
J. Taagholt, Danish Scientific Liaison Officer for Greenland, Copenhagen, DE

0900 7.2. Progress in Modelling the Polar Ionosphere from Solar and Magnetosphere Parameters
B. J. Watkins, S.-I. Akasofu and C. D. Fry, University of Alaska, Fairbanks, Alaska, UK

0930 7.3. Statistics of Auroral Radio Absorption in Relation to Prediction Models
J. K. Hargreaves, M. T. Feeney and C. J. Burns, University of Lancaster, Lancaster, UK

1000 Break

1100 7.5. Formation and Detection of High Latitude Ionospheric Irregularities
M. C. Lee, MIT, Cambridge, MA, J. A. Klobuchar and H. C. Carlson, AFGL, Hancom AFB, MA, US

1130 7.7. Direct In-Situ Measurements of Turbulent Zones in the Mesosphere (85-50 km) at 69 N (Andenes, Norway)
H. W. Widdell, Max Planck Institut, Lindau, FRG

1200 Lunch

Session VIII - Low Frequency Propagation

Chairman: Mr. J. Taagholt (DE)

1330 8.3. Comparison of D-Region Conductivity Profiles of the Disturbed Polar Ionosphere Calculated from Incident Particle Flux Data and by Inversion of VLF Sounding Data
E. C. Field and C. R. Warber, Pacific Sierra Research Corp., Los Angeles, CA, P. A. Kossey and J. E. Rasmussen, RADC, Hanscom AFB, MA, US

1430 Break

1500 8.4. World Atlas of Ground Conductivities with Particular Emphasis on the High Latitude Region
K. N. Stokke, Norwegian Telecommunications Administration, Oslo, NO

Friday, 7 June 1985

Session IX - Meteor Burst/Scatter

Chairman: Dr. H.J. BLYTHE (UK)

0900 9.1. Meteor Scatter Radio Communications at High Latitudes
P. S. Cannon, A. H. Dickson and M. H. Armstrong, Royal Aircraft Establishment, Farnorough, UK

0930 9.2. Characteristics of High Latitude Meteor Burst Propagation Parameters Over the 40-150 MHz Band
J. Ostergaard, Elektronik Centralen, Copenhagen, DE, J. E. Rasmussen, P. A. Kossey, M. J. Sowa, J. M. Quinn, RADC, Hanscom AFB, MA, US

1015 Break

1045 Round Table Discussion

Chairman: Prof. R. D. Hunsucker (US)

1215 Closing Ceremonies

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14. Abstract

This document summarizes the meeting and discusses the varied papers presented as well as the post-meeting round table discussion. Conclusions are drawn and recommendations put forth. This meeting was held to bring together ionospheric physicists, communications and systems engineers, plus managers and users of communications and surveillance systems from the NATO countries to exchange information on the subject of the symposium. Included in the scope of the meeting were: (1) detailed experimental studies of ionospheric irregularities and regular structure, (2) results of ionospheric modification (HF heating) experiments, (3) theoretical studies of ionospheric irregularity formation, (4) a global survey of ground conductivities, (5) results of disturbance modeling studies, (6) high latitude effects on the following systems: a) HF radio communication, b) trans-ionospheric communications, c) Satellite synthetic aperture radar (SAR), d) MF radio broadcasting, e) Spatially adative propagation, f) HF digital, g) Skywave HF sea-state radar and h) meteor burst communication.

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